# Overview:

# Photochemical Modeling for

# Bay Area 2004 Ozone Attainment Strategy

The Bay Area Colead Planning Agencies* are required to submit a State Implementation Plan (SIP) revision for ozone, the principal component of smog. The SIP revision, which will be submitted to the California Air Resources Board (CARB) and to the U.S. Environmental Protection Agency (EPA) in 2004, is an Ozone Attainment Strategy to show how the San Francisco Bay Area (Bay Area) will attain the 1-hour National Ambient Air Quality Standard (NAAQS) for ozone. The forecast of ambient ozone air quality into the future will be achieved through computer modeling. The modeling for this submittal will benefit from significant advances in data collection and model development, compared to the Attainment Assessment in the Bay Area's 2001 Ozone Plan. This report provides an overview of the new modeling work and provides a discussion of the expected results.

## Background

Ozone is not emitted directly into the air, but rather is formed in the atmosphere from other precursor species through a series of complex chemical reactions that take place in the presence of sunlight. Volatile organic compounds (VOC) and oxides of nitrogen (NOx) are the major ozone precursors. The formation of ozone near ground level depends on the amount, timing, and spatial patterns of precursor emissions. In addition, the magnitude and location of ozone concentrations depend on weather conditions, with the highest ozone occurring on hot, sunny days with little or no wind. Further complicating the issue is the fact that the chemical reactions that control ozone levels are nonlinear, which means that a reduction in precursor emissions under one set of background conditions could have a different effect on ozone concentrations than that same reduction with a different set of background conditions. Previous modeling studies and analyses of observations have suggested that the production of ozone in the Bay Area is limited by the availability of VOC, which means that Bay Area ozone is most effectively controlled through reductions in VOC emissions. These studies further suggest that reductions in NOx emissions produce smaller reductions in ozone and can even result in increased ozone in areas near the NOx reductions. This effect may prevail until the NOx reductions become a significant fraction of the total NOx inventory.

Because of these complexities, a complex computer modeling system is used to link precursor emissions to ozone levels, past and future. The technical details of how the

* The Colead Agencies for federal air quality planning in the Bay Area are: the Bay Area Air Quality Management District, the Metropolitan Transportation Commission, and the Association of Bay Area Governments.

modeling will be conducted are presented in the Bay Area's Modeling Protocol document available on-line at http://www.baaqmd.gov/planning/2004sip/2004sip.htm.

The Protocol has been developed by modeling experts under guidance of the Bay Area's Modeling Advisory Committee, which is composed of representatives of the three colead agencies, ARB, EPA, environmental and industrial groups, and neighboring air districts. Environ Corp., a well-known consulting firm with international operations and in-depth experience with air quality issues, has been contracted to conduct the ozone modeling for the San Francisco Bay Area.

The basic steps required for the computer modeling are as follows:

- Identify and collect a set of observations suitable for creating inputs to the modeling system and for evaluating the performance of the modeling system. This set of observations is used to form a database that includes meteorological measurements both near the ground and aloft, day-specific activity data for determining emissions, and measured concentrations of ozone and precursor pollutants near the ground and aloft. The observational database defines the historic period that is used for the base year modeling.
- For the historic period defined by the observations, apply a prognostic meteorological model to provide spatially and temporally-resolved meteorological inputs, such as winds and temperatures. These meteorological inputs are needed to specify how air pollution is transported within the Bay Area and throughout Central California.
- For the historic period defined by the observations, apply a computer model to compile and assign emissions from all the various sources of air pollutants: cars and trucks, industrial sources, paints and solvents, home products, lawn and garden equipment, etc.
- Using the meteorological inputs and the emissions inputs, apply a photochemical computer model to predict ozone levels. Field observations are used to evaluate the performance of the modeling system for one or more historic ozone episodes. If the modeling system is judged to be reliably representing the formation of ozone in the Bay Area and its surroundings, then the system is confirmed as a useful planning tool to predict future ozone levels. Future ozone formation is simulated based on new inputs that represent future growth in population, travel, and economic activity, with current or additional new air pollution control measures in effect.

## Field Observations

The Central California Ozone Study (CCOS) was a large field program conducted during the summer of 2000 to provide a more comprehensive and reliable data base for future ozone analyses. The study involved many sponsors and participants with a budget of over $8 million for the observational measurements. In addition, the CARB and local Air Quality Management Districts (AQMDs) provided substantial in-kind contributions to the study. The field measurement program covered a domain that includes much of northern California, extending north of Redding, and all of central California, including the San Francisco Bay Area and the San Joaquin Valley. A summary report on the CCOS field operations has been

completed and is available on-line at http://www.arb.ca.gov/airways/ccos/docs/ccosv3fdS0.zip.

The CCOS participants collected many special surface and upper-air meteorological and air-quality measurements. These complement the extensive permanent network of measurements that are routinely available. During the primary study period for CCOS, which extended from the beginning of July to the end of September, there was one period, Monday July 31st, 2000, where ozone exceeded the 1-hour NAAQS in the Bay Area. High ozone in the Central Valley followed on August 1st. Another high ozone event occurred on Thursday June 15, 2000, before the primary study period began. But there were some field study measurements in operation in June, beyond the routine data collection. The June 15 and July 31 episodes were deemed suitable for further analysis and computer modeling.

One of the main problems with field studies is that they only occur during a limited and pre-arranged window in time. So they often do not coincide with the air pollution episodes that would be most appropriate and most valuable for further study. One such episode occurred during July 11-12 in 1999, the summer before the CCOS project got into its field study phase. During the July 11-12 event, six ozone monitoring sites in the Bay Area exceeded the 1-hour NAAQS. Two additional factors were of interest: 1) High ozone occurred on a Sunday, when emission patterns differ from weekdays, and 2) The wind patterns are of a type that may result in pollutant transport to neighboring air basins. Because this was such a widespread event within the Bay Area and throughout Central California, this episode was also selected for computer modeling. Since no CCOS data are available for this time period, the modeling will rely on the extensive network of routinely-collected field measurements.

## Description of the Meteorology

High-ozone, smoggy days occur when precursor pollutant emissions meet with unfavorable summer weather conditions. (These days are unfavorable from the perspective of high temperatures and high ozone production, but may be otherwise quite pleasant summer days in the Bay Area.) During the summer, when the sunlight is intense, unfavorable conditions result when the Pacific high pressure system moves onshore and blocks weather systems into California and reduces the normal ventilating sea breeze. Within the group of high ozone days in the Bay Area, a recent classification study identified two different kinds of high-ozone days: 1) days with widespread ozone throughout the Bay Area and its surroundings, and 2) days with high ozone only at isolated locations. The July 1999 days were found to fall into the first category (widespread ozone); whereas, the two summer 2000 periods were found to belong in the second (isolated ozone). The modeling study underway will attempt to generate meteorological inputs for the July 1999 days and the June 2000 and July-August 2000 periods, so both types of days will be represented.

## Inventory of Pollutant Emissions

The CARB, with assistance from the AQMDs and consultants, is developing emissions inventories for all of Central California during each of the high-ozone periods described above. Separate, day-specific, modeling inputs are created for some major stationary sources

(seasonal and day-of-week adjusted emission rates are calculated), for on-road motor vehicles, and for off-road vehicles and area-distributed sources. There is also an emissions input for biogenic emissions, which include VOC from plants and trees and NOx from soils, especially soils rich with nitrogen-containing fertilizers. These inventories will be more accurate than previous versions because ARB's new motor vehicle emission model (EMFAC 2002) is used, and the stationary and mobile source calculations incorporate new activity data from the CCOS intensive study episodes.

## Computer Models Applied

The modeling project relies on the application of a number of different computer models. The meteorological model is the Regional Atmospheric Modeling System (RAMS), which the District staff has applied for many years with demonstrated good performance in the Bay Area. The emissions processing of episode-specific emissions is based on the 1995 Emissions Modeling System (EMS-95), the same model used by CARB to generate emissions for past SIPs in Central California, and for its current CCOS inventory development. The air quality model, the Comprehensive Air quality Model with extensions (CAMx), will take input from the RAMS model and the EMS-95 model and will be used to predict ozone. All of the selected models have been used in other areas for SIPs and/or regional regulatory analyses, and thus have been accepted by the EPA and many States for this purpose. The CAMx model was recently adopted by CARB for their SIP modeling of the CCOS episodes. CAMx supports a suite of *probing tools* to support sensitivity studies and an analysis of processes within the model that can be used to help insure the model is working correctly.

## Expected Results

We expect that our computer modeling work will produce reliable simulations of ozone production in the Bay Area and surrounding regions for at least some of the days we are attempting to model. For the periods that are successfully simulated, the modeling will provide

- the basis of a planning tool that will allow us to predict future ozone levels and the effects of further reductions in Bay Area precursor emissions.
- a demonstration that a selected suite of emission controls will result in attainment of the national 1-hour ozone standard by the year 2006.

The CARB has similar modeling efforts underway and is planning to model the same July-August 2000 episode we are modeling and an episode in September 2000 when ozone was high in the Central Valley (but not in the Bay Area). Our modeling, along with the modeling efforts underway at the CARB, will provide new and more credible evidence regarding the formation and transport of ozone in the Bay Area and central California.

The modeling being conducted for the 2004 Ozone Attainment Strategy will provide an improved technical foundation for Bay Area ozone planning compared to the modeling

conducted for the 2001 Ozone Attainment Plan. The current photochemical modeling incorporates several significant improvements.

First, the current modeling will examine three recent episodes (two episodes from 2000 and one from 1999) compared to one 1989 episode used for the 2001 Plan.

Second, the current modeling will be supported by more extensive field measurements. Modeling for the year 2000 episodes will use the CCOS field study data as opposed to the smaller scale 1989 Ozone Study.

Third, many improvements have been incorporated into the emission inventory modeling inputs, including EMFAC2002 for on-road motor vehicle emissions rather than EMFAC2001, area source emissions based on more recent population and employment projections, episode-specific emissions data for key stationary sources, and biogenic emission estimates based on more recent vegetation maps and algorithms for plant emissions.

Fourth, the meteorological model used for the analysis will be the latest generation of RAMS and the ozone model will be the latest version of CAMx, with the best representation of photochemical reactivity.

Finally, we are conducting the modeling work with the oversight of a Modeling Advisory Committee and will bring information about the modeling process to the public through meetings and postings to the District website.

We expect that all of these improvements and updates will result in improved emission reduction targets and a more open process.